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Placental transport of calcium and phosphorus in pigs

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1 Introduction

Accretion of calcium (Ca) and phosphorus (P) in fetal bone requires active transport from mother to fetus through the placenta. Although active transport of Ca and P has been described in sheep and in various other species [1, 25, 22] the factors mediating this process are not yet clear. One possible candidate for the regulation is vitamin D [23]. Support for this view comes from the presence of specific placental $1,25\text{-(OH)}_2\text{D}_3$ receptors in rats, from the presence of a vitamin D dependent calcium-binding protein (CaBP) [3, 18] and from placental 25-hydroxycholecalciferol-1-hydroxylase activities in humans [27] rats [24] and in guinea pigs [7].

In sheep, for example, fetal plasma levels of $1,25\text{-(OH)}_2\text{D}_3$ appear to be a primary factor for the regulation of transplacental Ca transport [5]. Other evidence, however, from Brommage and Deluca [2] indicated that transfer of Ca and P through the placenta of rats is independent of both maternal and fetal $1,25\text{-(OH)}_2\text{D}_3$ concentrations. From measuring feto-maternal concentration ratios of Ca and P in vitamin D deficient and in vitamin D repleted mother/fetus systems these authors found that transplacental gradients were unaffected by the presence of $1,25\text{-(OH)}_2\text{D}_3$ in either mother or fetus.

We have investigated the transport of Ca and P in pigs, using the "Hannover Pig Strain". These pigs suffer from inherited pseudo-vitamin D-deficiency rickets, type I [13]. They lack the renal cholecalciferol-1-hydroxylase activity [28] and have unphysiological low concentrations of $1,25\text{-(OH)}_2\text{D}_3$ in plasma. The animals depend on permanent pharmacological treatment with vitamin D [13] to prevent development of hypocalcemia, hypophosphatemia and florid rickets. The disease

Curriculum vitae

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is inherited by an autosomal recessive gene and clinical symptoms develop only in homozygote progeny [19]. The symptoms which develop at an age of four to six weeks [10] are almost identical to those found in humans with pseudo-vitamin D-deficiency rickets, type I [20]. Ca and P concentrations in plasma of homozygote rachitic piglets, however, are normal at birth. It was investigated which role vitamin D plays in regulating placental transport of Ca and P during the perinatal period in these pigs.

2 Material and methods

2.1 Animals and feeding

Thirty nine homozygote and heterozygote offspring of five litters from five sows were used for the study. To produce homozygote and heterozygote offspring a homozygote and a heterozygote parent animal were mated. Seventeen homozygote

piglets were produced by mating one homozygote and two heterozygote sows with one homozygote boar. Twenty two control piglets (heterozygotes and normals) were generated by mating one homozygote and three heterozygote sows with one homozygote and one normal control boar (table I).

The sows and boars were fed twice daily a grain/concentrate pig diet at maintenance level which contained 0.8% Ca and 0.6% P/kg DM.

Table I. Experimental animals and status (ho = homozygote, h = heterozygote)

Sow No. and status	Boar No. and status	Number of offspring and genotype ho/he
1 Homozygote	1 homozygote	10: 10/0
2 Homozygote	2 normal	8: 0/8
3 Heterozygote	2 normal	8: 0/8*
4 Heterozygote	1 homozygote	6: 3/3
5 Heterozygote	1 homozygote	7: 4/3

* approximately 50% heterozygote and 50% normal genotype

2.2 Blood sampling and analytical procedures

Adult homozygote animals were treated by i.m. injections of 10 mg of vitamin D₃ at intervals of four weeks. With the sows, treatment was discontinued from two months before conception to one day to one week after delivery. Two to 5 ml of arterial and venous blood were collected by puncture from the umbilical vessels during cesarian section at the 114th to 115th day of pregnancy. The sows were prepared for cesarian section by i.m. injection of 3 to 5 ml Azaperon (Stresnil ®) and i.v. injection of 3 to 6 ml Metomidat-HCl (Hypnodil ®) and epidural anesthesia with 0.7–1.2 ml of a local anesthetic agent (Hostacain ®). After finishing blood collection the umbilical cord was disconnected to separate the piglets from maternal blood supply. Maternal blood was obtained before parturition and during the operation by indwelling catheters from the internal jugular vein. The catheters were placed two to three weeks before parturition under anesthesia. The blood was heparinized and centrifuged at 3500 g for 10 min and the plasma was stored in 1.0 ml aliquots for further analysis at –25 °C. Plasma Ca was colorimetrically determined in 50 µl aliquots as cresolphthalein-

complex using the Boehringer Test Kit (No. 204382). The variation coefficient of the replicates at different times was $\pm 2\%$. Inorganic P was measured in plasma as molybdenumblue-complex [21]. The variation coefficient was $+ 3\%$.

The concentration of 1,25-(OH)₂D₃ was measured after separation of the methanol/methylenchloride extract by HPLC, following a procedure of LAMBERT et al. [15] and KAUNE and HARMEYER [11].

Briefly, 2 to 4 ml of plasma were extracted with a mixture of methanol/methylenchloride (2 + 1, v/v). The extract was fractionated on columns with Lipidex 5000 (Fa. Packard Instr. & Co., Hamburg, FRG) using a three step gradient of n-hexane in chloroform. The 3rd (45 + 55, v/v) hexane in chloroform mixture eluated the double hydroxylated metabolites of vitamin D. This fraction was brought to dryness and separated by normal phase HPLC. The HPLC elution program constituted of a 30 min gradient of isopropanol in n-hexane. The eluated fractions which contained 1,25-(OH)₂D₃ were combined and brought to dryness and quantified by a radioimmunoassay using an antibody from sheep, kindly provided by A. D. CARE, Dept. Animal Physiology and Nutrition, University of Leeds, GB. The reference substances were kindly provided by Hoffmann-La Roche, Basel, Basel, Switzerland.

For recovery measurements known amounts of 1,25-dihydroxy (26, 27-methyl-³H)-cholecalciferol (spec. activity: 6.51 TBq/mmol; Fa. Amersham Buchler, Braunschweig, FRG) were added before extraction of plasma. The intra- and interassay variances were $+ 14\%$ (n = 16) and 9.2% (n = 8), respectively.

2.3 Statistics

Differences in the plasma Ca and P concentrations between groups were tested with Student's t-test with different numbers of n in the two groups. The arterio-venous differences in fetal plasma were tested of significance with a paired t-test.

3 Results

3.1 Fetal and maternal concentrations of Ca and P in plasma

a) Calcium: Mean concentrations of Ca in heterozygote sows at parturition were 2.34 mmol/l and significantly higher than those in homozygote sows (1.58 mmol/l) (table II). Ca concentrations

Table II. Concentrations of calcium (mmol/l) in maternal and fetal plasma of pigs at term (mean \pm SD).

Group of animals	(I) Maternal plasma jugular vein (n)	(II) Arterial plasma fetus (V. umb) (n)	(III) Concentration difference	significance		
				between rows	for column	p <
1) Homozygote sows and their fetuses	1.58 \pm 0.18 (6)	2.96 \pm 0.08 (15)	1.35 \pm 0.14	1:2 1:2 1:2	(I) (II) (III)	0.001 n. s. 0.001
2) Heterozygote sows and their fetuses	2.34 \pm 0.07 (6)	3.23 \pm 0.10 (17)	0.909 \pm 0.10			
3) Heterozygote sows and their heterozygote fetuses	2.34 \pm 0.07 (6)	3.22 \pm 0.05 (11)	0.887 \pm 0.08	3:4	(II)	n. s.
4) Heterozygote sows and their homozygote fetuses	2.29 \pm 0.10 (2)	3.25 \pm 0.04 (6)	0.965 \pm 0.08			
5) Homozygote sows and their heterozygote fetuses	1.76	2.99 \pm 0.07 (8)	1.23 \pm 0.07	5:6	(II)	n. s.
6) Homozygote sows and their homozygote fetuses	1.45	2.91 \pm 0.06 (7)	1.46 \pm 0.06			

in arterial plasma of fetuses from homozygote and heterozygote sows were 2.96 mmol/l and 3.23 mmol/l, respectively, and were statistically not different (table II; 1:2 (II) n. s.). Although fetal Ca in offspring from hypocalcemic homozygote sows was slightly lower than that in offspring from normocalcemic heterozygote mothers the fetal/maternal Ca gradient was significantly greater in the homozygote mother/piglet system than that in the heterozygote mother/piglet system (figure 1 A,

table II). Plasma Ca in homozygote and in heterozygote offspring from the same sows was the same showing that the genotype of the fetus had no significant influence on the feto/maternal concentration gradient (table II; 5:6 (II) n. s.).

b) Phosphate: The mean concentration of P in plasma of heterozygote sows at parturition (2.33 mmol/l) was also significantly higher than that in homozygotes, 1.26 mmol/l (table III). Fetal con-

Table III. Concentrations of phosphate (mmol/l) in maternal and fetal plasma of pigs at term (mean \pm SD).

Group of animals	(I) Maternal plasma jugular vein (n)	(II) Arterial plasma fetus (V. umb) (n)	(III) Concentration difference	Significance		
				between rows	for column	p <
1) Homozygote sows and their fetuses	1.26 \pm 0.186 (6)	2.82 \pm 0.270 (13)	1.51 \pm 0.265	1:2 1:2 1:2	(I) (II) (III)	0.001 n. s. 0.001
2) Heterozygote sows and their fetuses	2.33 \pm 0.09 (6)	2.82 \pm 0.184 (16)	0.65 \pm 0.201			
3) Heterozygote sows and their heterozygote fetuses	2.23 \pm 0.09 (6)	2.77 \pm 0.170 (10)	0.57 \pm 0.276	3:4	(II)	n. s.
4) Heterozygote sows and their homozygote fetuses	2.28 \pm 0.09 (2)	2.89 \pm 0.194 (6)	0.79 \pm 0.204			
5) Homozygote sows and their heterozygote fetuses	1.42	2.88 \pm 0.275 (8)	1.46 \pm 0.276	5:6	(II)	n. s.
6) Homozygote sows and their homozygote fetuses	1.16	2.73 \pm 0.262 (6)	1.57 \pm 0.262			

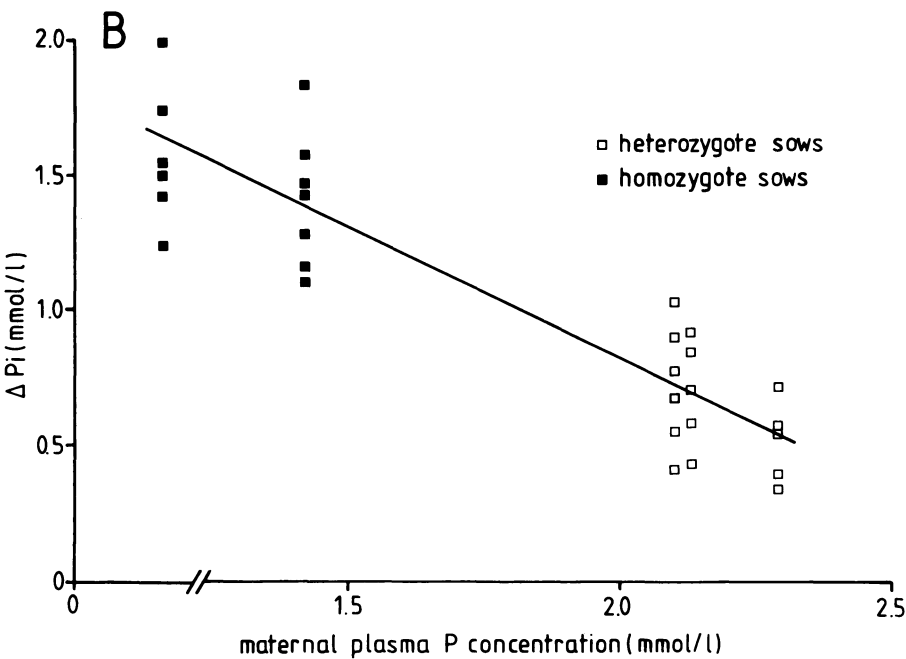


Figure 1B.

Table IV. Arterial and venous concentrations of calcium and phosphate (mmol/l) in umbilical plasma of pig fetuses at term (mean \pm SD).

Group of fetuses	(I) Arterial plasma (V. umb)	(n)	(II) Venous plasma (Aa. umb)	(n)	n	p <
1) Fetuses from homozygote sows	Ca: 2.96 \pm 0.08 P: 2.82 \pm 0.270	(15) (13)	2.89 \pm 0.09 2.19 \pm 0.104	(17) (14)	(14) (12)	0.01 0.001
2) Fetuses from heterozygote sows	Ca: 3.23 \pm 0.10 P: 2.87 \pm 0.184	(17) (16)	3.11 \pm 0.08 2.35 \pm 0.109	(21) (14)	(17) (14)	0.001 0.001
3) Homozygote fetuses from homozygote and heterozygote sows	Ca: 2.96 \pm 0.162 P: 2.81 \pm 0.236	(13) (12)	3.07 \pm 0.182 2.25 \pm 0.143	(17) (13)	(13) (11)	0.01 0.001
4) Heterozygote fetuses from homozygote and heterozygote sows	Ca: 3.12 \pm 0.130 P: 2.82 \pm 0.222	(19) (18)	3.04 \pm 0.106 2.29 \pm 0.119	(21) (15)	(18) (15)	0.01 0.001

(n) = number of plasma samples, n = number of differences

b) Arterio-venous differences in fetal plasma: The AV-concentration differences of 1,25-(OH)₂D₃ in plasma of fetuses supplied with the blood from homozygote sows was always negative (42.3 vs. 25.0; table V) but was zero in fetuses which were supplied with blood from heterozygote mothers (47.6 vs. 54.1; table V). This effect was not influenced by the genotype of the fetus.

Table V. Concentrations of 1,25-(OH)₂D₃ (pg/ml) of maternal and fetal plasma at term (mean ± SD).

Group of animals	(I) Maternal plasma jugular vein	(II) Arterial plasma fetus (V. umb)	(III) Venous plasma fetus (Aa. umb)	Significance		
				between rows	for co- lumn	p <
1) Homozygote sows and their fetuses	25.5 ± 8.27 (2)	25.0 ± 2.60 (6)	42.3 ± 6.69 (7)	1:2	(II)	0.002
2) Heterozygote sows and their fetuses	84.1 ± 25.60 (3)	54.1 ± 19.24 (11)	47.6 ± 17.31 (11)	1:2 1:2	(I) (III)	0.1 n. s.
3) Homozygote fetuses and their sows	76.1 ± 39.28 (3)	35.3 ± 17.36 (7)	38.7 ± 11.40 (8)	3:4	(III)	n. s.
4) Heterozygote fetuses and their sows	69.6 ± 35.31 (4)	49.9 ± 21.35 (10)	54.3 ± 18.85 (10)			
5) Homozygote fetuses and their heterozygote sows	98.7 ± 5.51 (2)	41.5 ± 21.70 (4)	32.8 ± 11.73 (4)	5:7	(III)	0.025
6) Homozygote fetuses and the homozygote sow	31.0 (1)	27.0 ± 1.35 (3)	44.1 ± 8.54 (4)	6:8	(III)	n. s.
7) Heterozygote fetuses and the heterozygote sow	84.1 ± 25.60	61.4 ± 13.80	56.1 ± 14.30			
8) Heterozygote fetuses and the homozygote sow	19.3 (1)	23.0 ± 1.83 (3)	39.8 ± 3.17 (3)			

4 Discussion

Investigation of feto-maternal Ca homeostasis in the "Hannover Pig Strain" showed that the placentas of homozygote hypocalcemic sows maintained significantly greater concentration gradients for Ca and P than the placentas of heterozygote sows. Thus the ability of the placenta to transport Ca and P to the fetus appears to be independent from the vitamin D-status. There was little doubt about the vitamin D deficient status of the homozygote sows, since hypocalcemia in the untreated sows was sometimes acute at birth and was associated with cardiovascular symptoms and immobility. In these cases the sows were substituted by continuous intravenous infusions of Ca immediately after delivery.

Our observations differ somewhat from those of Ross et al. [22] who observed a decrease or increase in fetal Ca after an acutely induced hypocalcemia and hypercalcemia in pregnant normal sows, respectively. CARE [6] reported, however, that there was no permanent decrease in fetal Ca after acutely induced (30 to 80 min) hypocalcemia in sows by intravenous EDTA-Infusions.

The hypocalcemia in our rachitic sows resulted from discontinuation of vitamin D-treatment and from the lack of renal 1,25-(OH)₂D₃ production [28]. Maternal 1,25-(OH)₂D₃ concentrations of 25 pg/ml in the homozygote sows were similar to those of nonpregnant adult pigs of the rachitic strain and were always seen to be too low to maintain normocalcemia [13].

The vitamin D-hormone concentration in plasma of homozygote fetuses which were derived from both homozygote and heterozygote sows, of 45 and 33 pg/ml, respectively, are considered to be too low to induce placental transfer of Ca and P to the fetus. This is supported by the observation that an extremely low plasma 1,25-(OH)₂D₃ concentration in some homozygote fetuses (considerably below 25 pg/ml) showed to have no adverse effect on Ca and P transport from the mother into these fetuses. In addition, we found that homozygote and heterozygote piglets at term had no detectable intestinal 1,25-(OH)₂D₃ receptors [12]. The receptor started to appear between 1 and 2 weeks of extra-uterine life.

The mean $1,25\text{-(OH)}_2\text{D}_3$ concentrations in plasma of heterozygote fetuses (54 pg/ml), and in homozygote fetuses (39 pg/ml) were not correlated with plasma Ca and P concentrations of the animals. We conclude from this observation that in pigs potential renal $1,25\text{-(OH)}_2\text{D}_3$ production in either mother of fetus is not essential for maintenance of the Ca homeostasis of the pig fetus. In addition, both homozygote and heterozygote piglets showed normal intestinal absorption of Ca during the first two weeks of extra-uterine life [14]. Hypocalcemia and rickets developed in homozygote piglets not before an age of three to five weeks. Vitamin D-hormone concentrations in plasma, however, remained low during the first three to five weeks of life. Other support for the view of placental Ca transport being independent from vitamin D comes from studies with vitamin D depleted pregnant rats [2]. In these studies vitamin D deficient rat fetuses had normal blood concentrations of Ca and P [9] and placental gradients of these elements were higher between vitamin D depleted than between vitamin D repleted mother/fetuses [2].

The independence of rat placental calbindin from vitamin D [16] lends further support to the view of a vitamin D independent regulation of placental Ca transport in the rat. A similar finding has been made by TWARDOCK and AUSTIN [25] in guinea pigs who reported that a placental Ca gradient was also maintained after fetal nephrectomy.

Summary

The role of vitamin D in regulating placental transport of calcium and phosphate in pigs was studied using the "Hannover Pig Strain" which suffers from pseudo-vitamin D-deficiency rickets, type I. Sows and fetuses of normal phenotype (heterozygotes) and of homozygote phenotype which suffered from clinical symptoms of rickets were used. The homozygote animals are devoid of renal 25-cholecalciferol-1-hydroxylase. In the rachitic sows which normally depend on treatment with pharmacological doses of vitamin D_3 at intervals of four to six weeks, vitamin D-treatment was discontinued two months before conception. Ca, P and $1,25\text{-(OH)}_2\text{D}_3$ concentrations in plasma of sows and fetuses (Aa. umb., V. umb.) were measured in samples obtained at term during cesarian section.

Mean concentrations of Ca and P in heterozygote sows at parturition were 2.34 mmol/l and 2.33 mmol/l, respectively, and were significantly higher than in homozygote sows, 1.58 mmol/l and 1.26 mmol/l, respectively.

This contrasts somewhat with observations made in sheep fetuses. In this species fetal nephrectomy resulted in a significant fall of the fetal $1,25\text{-(OH)}_2\text{D}_3$ concentration and abolished the placental gradient for Ca [23, 17]. Also in mice placental calbindin appears to be more responsive to the maternal vitamin D supply than in rats [4].

The vitamin D-hormone in maternal and fetal plasma of homozygote animals does not originate from renal production (unpublished observation). Extrarenal production of $1,25\text{-(OH)}_2\text{D}_3$, however, has been demonstrated to occur in pregnant rats [8, 26] and in human decidua [27]. We do not think that the slightly higher $1,25\text{-(OH)}_2\text{D}_3$ concentrations in the umbilical venous plasma of heterozygote fetuses (54 pg/ml) compared to homozygote fetuses (39 pg/ml) indicate a contribution of the fetal heterozygote kidney to $1,25\text{-(OH)}_2\text{D}_3$ production.

Pig placenta is permeable to $1,25\text{-(OH)}_2\text{D}_3$ [6]. The placental differences of $1,25\text{-(OH)}_2\text{D}_3$ found in these studies indicate a placental transfer of $1,25\text{-(OH)}_2\text{D}_3$ from homozygote and heterozygote fetuses to the homozygote sows and from heterozygote sows to the homozygote fetus (table V). The physiological significance of this passage is yet unknown since no significant placental concentration differences of vitamin D-hormone were found in the heterozygote mother/fetus system. This contrasts also with findings in sheep where fetal concentrations of $1,25\text{-(OH)}_2\text{D}_3$ were found to be markedly higher (88 pg/ml) than in the ewe (58 pg/ml) [23].

Ca concentrations in plasma of the umbilical vein of fetuses from both homozygote and heterozygote sows were normal, however, (3.23 mmol/l and 2.96 mmol/l, respectively) and statistically not different from each other. No significantly different P concentrations in arterial plasma of fetuses from heterozygote or homozygote sows were seen, either. The concentrations of Ca and P in the arterial umbilical plasma were significantly higher ($p < 0.001$) than in venous plasma of both homozygote and heterozygote fetuses, indicating net placental transfer of these elements in both genotypes.

The concentration of $1,25\text{-(OH)}_2\text{D}_3$ in hypocalcemic sows at term (25.5 ± 8.25 pg/ml) was significantly lower than that in the normocalcemic (heterozygote) sows (84.1 ± 25.6 pg/ml). The $1,25\text{-(OH)}_2\text{D}_3$ concentration in arterial plasma of fetuses from homozygote sows was only 46% that of fetuses from normocalcemic sows which showed transfer of calcitriol from mother to fetus. It is concluded from these studies that in pigs, renal

production and physiological concentrations of 1,25-(OH)₂D₃ in either mother or fetus is not essential for the

maintainance of the Ca and P homeostasis in the fetal-maternal system.

Keywords: Calcium, calcitriol, perinatal period, pigs, phosphorus, transplacental transport, vitamin D.

Zusammenfassung

Plazentarer Transport von Calcium und Phosphat beim Schwein

Wir untersuchten die Rolle des Vitamin D bei der Regulation des plazentaren Transports von Calcium und Phosphat am "Hannover Pig Strain", das an einer Rachitis infolge eines Pseudo-Vitamin-D-Mangels (Typ 1) leidet. Muttertiere und Feten mit normalem Phänotyp (Heterozygote) sowie mit klinischen Zeichen der Rachitis (Homozygote) wurden in die Studie einbezogen. Die homozygoten Tiere hatten keine renale 25-Cholecalciferol-1-Hydroxylase. Die Sauen mit Rachitis, die normalerweise pharmakologische Dosen von Vitamin D₃ in Abständen von 4–6 Wochen erhalten, wurden jetzt zwei Monate vor Konzeption nicht mehr mit Vitamin D behandelt. Die Ca-, P- und 1,25-(OH)₂D₃-Konzentrationen im Plasma von Muttertieren und Feten (Aa. umb., V. umb.) wurden in Proben gemessen, die während der Geburt bei der Sectio caesarea gewonnen wurden.

Die mittleren Konzentrationen von Ca und P waren bei den heterozygoten Muttertieren während der Geburt signifikant höher als bei den homozygoten Tieren (2.34 mmol/l und 2.33 mmol/l gegenüber entsprechend 1.58 mmol/l und 1.26 mmol/l). Die Ca-Konzentrationen in der Umbilicalvene der Feten waren bei homozygoten

und heterozygoten Tieren normal (3.23 mmol/l und 2.96 mmol/l) und statistisch nicht signifikant unterschiedlich. Auch die P-Konzentrationen im arteriellen Plasma der Feten waren bei homozygoten und heterozygoten Müttern vergleichbar. Die Ca- und P-Konzentrationen im Nabelarterienplasma waren jedoch sowohl bei homozygoten wie heterozygoten Feten signifikant höher ($p < 0.001$), was auf einen Netto-Transport dieser Elemente via Plazenta bei beiden Genotypen hinweist.

Die Konzentration von 1,25-(OH)₂D₃ bei hypocalcämischen Muttertieren zum Geburtszeitpunkt war signifikant niedriger als bei normocalcämischen (heterozygoten) Tieren (25.5 ± 8.25 pg/ml versus 84.1 ± 25.6 pg/ml). Die 1,25-(OH)₂D₃-Konzentration im arteriellen Plasma von Föten von homozygoten Sauen betrug lediglich 46% derjenigen, die bei Feten von normocalcämischen Muttertieren gefunden wurde, was auf einen Calcitriol-Transfer von der Mutter zum Fetus weist.

Wir schließen aus unseren Ergebnissen, daß beim Schwein eine renale Produktion und physiologische Konzentrationen von 1,25-(OH)₂D₃ sowohl bei der Mutter wie beim Feten nicht essentiell sind für die Aufrechterhaltung der Ca- und P-Homöostase des fetomater-nalen Systems.

Schlüsselwörter: Calcium, 1,25-(OH)₂D₃, Phosphat, plazentarer Transport, Rachitis infolge Vitamin-D-Mangel (Typ 1), Vitamin D.

Résumé

Transport placentaire du calcium et du phosphore chez le cochon

On a étudié le rôle de la vitamine D dans la régulation du transport placentaire du calcium chez le cochon en utilisant des truies "Hannover Strain" qui présentent un rachitisme de type I par déficience en pseudo-vitamine D. On a utilisé des truies et des fœtus de phénotype normal (hétérozygotes) et de phénotype homozygote qui présentent des symptômes cliniques de rachitisme. Les animaux homozygotes n'ont pas de 25-cholecalciférol-1-hydroxylase rénale. Chez les truies rachitiques qui dépendent normalement d'un traitement à doses pharmacologiques de vitamine D₃, toutes les 4 à 6 semaines, on a interrompu le traitement deux mois avant la conception. Sur des prélèvements obtenus à terme au cours de césariennes, on a mesuré dans le plasma des truies et des fœtus (artère et veine ombilicale) le Ca, le P et la 1,25-(OH)₂D₃.

Lors de la parturition les concentrations moyennes de Ca et de P chez les truies hétérozygotes sont de 2,34 mmol/l et de 2,33 mmol/l, respectivement, et elles sont significativement plus élevées que chez les truies homo-

zygotes, 1,58 mmol/l et 1,26 mmol/l, respectivement. Les concentrations de Ca dans le plasma de la veine ombilicale de fœtus des truies homozygotes et hétérozygotes sont normales, toutefois, (respectivement 3,23 mmol/l et 2,96 mmol/l) et ne sont pas significativement différentes l'une de l'autre. Il n'a pas été trouvé de différences significatives dans les concentrations de P du plasma artériel chez les fœtus de truies hétérozygotes et homozygotes. Les concentrations de Ca et de P du plasma artériel ombilical sont significativement plus élevées ($p < 0,001$) que dans le plasma veineux des fœtus homozygotes et hétérozygotes, ce qui traduit un transfert placentaire net de ces éléments, quel que soit le génotype. La concentration de 1,25-(OH)₂D₃ chez les truies hypocalcémiques à terme ($25,5 \pm 8,25$ pg/ml) est significativement inférieure à celle des truies normocalcémiques (hétérozygotes) ($84,1 \pm 25,6$ pg/ml). La concentration de 1,25-(OH)₂D₃ artérielle plasmatique chez les fœtus de truies homozygotes est seulement de 46% de celle des fœtus de truies normocalcémiques, ce qui témoigne du transfert du calcitriol de la mère au fœtus.

On conclut de ces études que chez le cochon, la produc-

tion rénale et les concentrations physiologiques de 1,25-(OH)₂D₃ chez la mère et chez le fœtus ne sont pas

essentiels pour la maintenance de l'homéostasie du calcium et du P dans le système fœtomaternel.

Mots-clés: Calcium, 1,25-(OH)₂D₃, phosphore, rachitismes par carence en pseudovitamine D, type I, transport placentaire, vitamine D.

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